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CHARACTERIZATION OF POTENTIALLY EXPLOSIVES-CONTAMINATED SITES AT CFB GAGETOWN, 14 WING GREENWOOD AND CFAD BEDFORD

by

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ABSTRACT

Some activities of the Canadian Forces such as firing practice, storage and demolition procedures may cause the dispersion of energetic compounds in the environment. These compounds should be closely monitored due to their highly specific physical, chemical and toxicological properties. In Canada, limited efforts have been spent in the past to examine this particular environmental threat. This report details the characterization of four potentially explosives-contaminated sites located at Canadian Forces Base (CFB) Gagetown, 14 Wing Greenwood and at Canadian Forces Ammunition Depot Bedford. The sampling and analytical methods are described and the results are presented. In general, our results show a non-presence to a low contamination level (<15 mg/kg). However, the Wellington Antitank Firing Range at CFB Gagetown showed relative high levels of contamination by HMX, a high explosive compound used in many antitank rockets. This work should help the Canadian Forces to pursue their operational activities, while minimizing the impacts on the environment by providing a better comprehension of the source of contamination and helping to minimize the environment impacts in the future.

RÉSUMÉ

Certaines activités des Forces canadiennes comme les exercices de tir, l'entreposage et la démolition de munitions peuvent entraîner la dispersion de composés énergétiques dans l'environnement. Ces composés représentent une nouvelle gamme de contaminants pour l'environnement étant donné qu'ils possèdent des propriétés particulières au point de vue physique, chimique et toxicologique. Au Canada, cette menace environnementale n'a pas été vraiment envisagée et elle est peu documentée. Ce rapport décrit la caractérisation de quatre sites potentiellement contaminés aux explosifs situés sur la base des Forces canadiennes (BFC) de Gagetown, à la 14e escadre de Greenwood et au dépôt de munitions des Forces canadiennes de Bedford. Les méthodes d'analyse et d'échantillonnage y sont décrites et les résultats obtenus sont présentés. En général, nos résultats montrent une contamination relativement faible (<15 mg/kg), voire nulle, sur certains sites. Cependant, on retrouve une contamination plus prononcée en HMX, un explosif présent dans plusieurs armes antichars, sur le site de tir antichar de Wellington, BFC Gagetown. Ce travail permettra aux Forces canadiennes de poursuivre leurs activités opérationnelles tout en minimisant l'impact sur l'environnement grâce à une meilleure compréhension de la source de contamination.

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EXECUTIVE SUMMARY

It is in the best interest of the Department of National Defence (DND) to find practical, economical and effective solutions to eliminate contaminants from soils and groundwater. Within the context of base closures and demilitarization, the Defence Research Establishment Valcartier (DREV) initiated, six years ago, an R&D program to study the environmental impacts of energetic materials, specifically those that are to be found in the CF ammunition stockpile. Activities such as firing practice, storage and demolition procedures may cause the dispersion of energetic compounds in the environment. Energetic compounds are just now being recognized as environmental contaminants compared to other contaminants such as heavy metals, petroleum compounds or organic solvents. They are also unique of concern, because of their specific chemical, physical and toxicological properties. It is to DND's advantage to implement environmentally benign defence activities. This involves scrutinizing all defence activities to make sure they have no adverse impact on the surrounding environment.

This report presents the results obtained from the characterization of four different sites: an operational antitank firing range, a grenade range, an open burning/open detonation (OB/OD) range and a potentially contaminated site. We observed a non-presence to a low (<15mg/kg) contamination level of explosive at all sites. However, we found a high degree of contamination at the Wellington Antitank Firing Range, CFB Gagetown. This is caused by the ammunition system used on these sites, which led the dispersion of energetic materials in the environment, mainly from the melt-cast explosive included in the firing system, which contained octol type 2, a mix of two explosives compounds; 2,4,6-trinitrotoluene (TNT) and cyclo-1,3,5,7 tetramethylene-2,4,6,8 tetranitramine (HMX). High levels of HMX can be found on the surface soil of this site, while TNT is suspected to leach to the groundwater table. From the four different sites sampled, conclusions are drawn on the source of contamination and on the ways to minimize the impact in the future. Furthermore, another R&D effort has led to the development of a technology that now offers a remedial action for the contaminated sites. The overall work described in this report should help DND to pursue their operational activities, while minimizing the impacts on the environment by providing a better comprehension of the source of contamination and helping to minimize these impacts in the future.

NOMENCLATURE

ACN	Acetonitrile
ATR	Antitank Range
CFAD	Canadian Forces Ammunition Depot
CFB	Canadian Forces Base
DND	Department of National Defence
DREV	Defence Research Establishment Valcartier
EIA	Enzyme Immunoassay
HMX	High Melting Explosive or Cyclo 1,3,5,7-tetramethylene-2,4,6,8 tetranitramine
HPLC	High Performance Liquid Chromatography
nm	Nanometer
OB/OD	Open Burning/Open Detonation
RDX	Research Development Explosive or Cyclo-1,3,5-trimethylene-2,4,6-trinitramine
R&D	Research and Development
TNT	2,4,6-trinitrotoluene

1.0 INTRODUCTION

Identifying and developing economical and effective methods to eliminate undesirable contaminants from the soil and groundwater is of increasing worldwide environmental interest and importance. The task is all the more critical and complex when the contaminants are energetic materials, which are the main components of gun powders, explosive warheads and solid rocket propellants. Even if site characterization has been well documented over the last twenty years, only little is known about the environmental behavior of energetic compounds. The new international context with the end of the Cold War has resulted in the closing of many military bases and a growing awareness in environmental issues. This awareness has led many countries to integrate R&D programs related to the environmental impacts of energetic materials. Over the last ten years a large effort has been dedicated internationally on the characterization of the extent of explosives contamination on a large number of ammunition plants and military depots (Refs. 1-4). The contaminants most often observed were TNT (2,4,6-trinitrotoluene), RDX (Cyclo-1,3,5-trimethylene-2,4,6-trinitramine) and their manufacturing impurities, and environmental transformation products (Ref. 5). More recently, a detailed protocol for the characterization of sites contaminated by explosives has been published: it covers all pertinent aspects of site characterization and will serve as a reference guide in future samplings of explosives-contaminated sites (Ref. 6). The potential negative health and environmental impact of energetic materials justified this effort.

In a general effort to assess the environmental impacts of the Canadian Forces operational activities, DREV scientists have characterized many potentially explosives-contaminated sites. In general, low levels (<15 mg/kg) of multi-contamination by explosives were found, demonstrating that the detonation of ammunition is a relatively clean process, which has a minimal impact on the environment. However, an exception was encountered at some Canadian antitank firing ranges where high levels of HMX were found in the surface soils (Refs. 7-10). Similar results were obtained on an U.S. antitank firing range recently characterized (Ref. 11).

This report presents the results obtained from the characterization of four potentially explosive-contaminated sites located at three different locations: Canadian Force Base Gagetown (CFB Gagetown), 14 Wing Greenwood and Canadian Forces Ammunition Depot, Bedford (CFAD Bedford). This work was carried out in August 1998 under WU 2ng11, "Characterization of DND Sites Contaminated with Energetic Materials" and co-

sponsored by a reference coming from the Directorate General Environment (DGE) through the Directorate of Ammunition Program Management (DAPM).

2.0 DESCRIPTION OF TEST SITES

Four potentially contaminated sites were sampled between the 3rd and the 8th of August 1998: the Wellington Antitank Firing Range, the Castle Grenade Range at CFB Gagetown, one potentially contaminated site at 14 Wing Greenwood and finally an OB/OD site at CFAD, Bedford. Pictures and scheme of those sites can be seen in Figs 1 to 9. These four sites differ in their usage, frequency of use and soil type. In each case, the extent of surface soil contamination was assessed. Different weapons system and energetic materials have been used in the past on those sites. All the characteristics of the soils, the site, weapons systems and energetic materials used will be described.

2.1 Wellington Antitank Firing Range, CFB Gagetown

CFB Gagetown is one of the largest CF land bases in eastern Canada; many firing ranges are frequently used for operational training, including the Wellington Antitank Firing Range. This triangular shape range is about 1.2 km^2 and has four target tanks. All the tanks are fairly visible from the firing point and the area is sparsely vegetated with bushes and swamps, as shown in Fig. 3. The soil around the targets is covered with topsoil, small rocks and grass. Targets 2 and 3 have small swamps, as shown in Fig. 6. Metallic shrapnel is dispersed all over the site, mostly nearby the four targets. This site is an active firing range and has been used all year long for more than 30 years. Weapons like the M-72 A5 66-mm is fired on a routine basis by the Canadian Forces and also by international allied forces, like USA, which were present when we sampled the site. The M-72 A5 66-mm weapon system is of U.S. design and manufactured in Norway (Ref. 12)

2.2 Castle Grenade Range, CFB Gagetown

The Castle Grenade Range at CFB Gagetown is an important operational grenade training facility. This rectangular shape range is about 1500 m^2 and has been used for more than 30 years by the Canadian Forces on a routine basis. The area has little vegetation and the soil is sandy with small spots of grass. Furthermore, the soil is clean from any metal pieces or scrap. In the past, the Canadian Forces have fired the M-36 hand grenade and are currently firing the M-67 hand grenade. C-4 is also used to detonate unexploded grenades.

2.3 14 Wing Greenwood

14 Wing Greenwood is one of the largest air force bases in eastern Canada. This base is used for maritime patrol, transport and combat support maritime operations. No potentially contaminated sites were expected from this base, except for a small site located near Bldg. 14, as shown in Fig 8. The Technical Department of the Environmental Office told us that a small site of about 150 m^2 might be contaminated with heavy metals and energetic materials. This suspicion occurred when 14 Wing Greenwood decided, a few years ago, to expand Bldg. 14 where subsequent excavation exposed an accumulation of old metal pieces that might have been metallic shrapnel. Since then, the site has been quarantined and is delimited with fences. The site is sparsely covered with small trees, bushes and plants. The sandy soil is mostly covered with grass, with some exposed spots of sand. No metallic shrapnel or scraps were found on the site and we have no information about the origin or type of energetic material that we could find.

2.4 CFAD Bedford

CFAD Bedford is a large ammunition depot in eastern Canada. It is located in the Halifax Bay area and presents many different buildings with ammunition stocks mostly used for maritimes operations. The potentially contaminated site is mainly used for the destruction of out-of-specification materials by open burning and open detonation (OB/OD). At this time, few OB/OD operations are carried out due to less activity and to the OB/OD limited quantity requirement. Large quantities are usually sent to other OB/OD facilities. However, in the past, this ammunition depot have burned and destroyed large quantities of energetic materials. A site near Bldg. 188 was identified by CFAD personnel to be the place where the majority of OB/OD activities were taking place. Behind Bldg. 188, which we will call Area A, there is a small slope, as shown in Fig. 9. This place presented limited vegetation where the most OB/OD operations were taking place. There, the soil is mostly sandy and sprinkled with rocks. Area B, in front of Bldg. 188 (as shown in Fig. 9) is also potentially contaminated with energetic materials as suggested by CFAD personnel. Area B consists of a concrete pad with grass around it and surrounded by ramparts. No metallic shrapnel or scraps were visible in Areas A and B when we visited the site.

3.0 SAMPLING STRATEGY

The sampling strategy was almost the same for all sites as there was not much difference between the type of soil, type of vegetation and the purpose of the sampling. The four sites sampled were not cleared at level 2 before our visit. Therefore, only surface sampling was allowed on these sites with the presence of CF ammunition specialists to ensure the safety of the team, as recommended in Ref. 6. Usually, when we first visit a site, only surface soil is sampled to detect contamination by energetic materials. If a concentration is detected, further evaluation, like sub-surface soil and groundwater, takes place in order to assess the depth profile of the contamination.

3.1 Wellington Antitank Firing Range, CFB Gagetown

It was the first time we were evaluating the contamination of energetic materials at the Wellington Antitank Firing Range, CFB Gagetown. The objective was to assess the contamination by energetic materials but, most specifically, the concentration of HMX usually present at Canadian antitank ranges, as suggested by our past studies (Refs. 7-10). For this first sampling, a limited number of 11 composite samples were collected, with four of them taken around each target labeled 1 and 3 (Fig. 6). No sampling was taken at Targets 2 and 4 because we had no clearance from the ammunition specialists due to unexploded ordnance present near the targets. The strategy consisted in collecting composite samples at an average distance of 1 m from the targets in the four directions. The samples were labeled from W1 and W3 from A to D, as shown in Fig. 6. Three other samples were collected; WX, a composite sample taken between Targets 1 and 2, WY a composite sample taken between the gravel road and Target 2, and finally WZ a composite sample taken from soil all around Target 3. Each composite sample, except for WZ, consisted of approximately 10 sub-samples taken randomly in a circular pattern at an average distance of 1 m from the target. For Target 3, the soil was sampled from the bottom of a swamp at W3D. Many duds and leaching broken casings were present beside the targets and our attention was directed to make sure no metallic shrapnel was moved for security purposes.

3.2 Castle Grenade Range, CFB Gagetown

As for the Wellington Antitank Firing Range, no level 2 clearance was performed on the Castle Grenade Range prior to our sampling. Consequently, we were authorized to sample only surface soils. Because the range was covered with sandy soil and small spots of grass we had no difficulty to cover the extent of the site. A total of 11 samples labeled CW1 to CW8 and C1 to C3 were taken all around the site in such a way to cover the complete area, as shown in Fig. 7. Each sample consisted of a circular composite built out of approximately 10 sub-samples taken randomly in a circular way around a fixed point, at an average distance of 0.5 m around the point. Three composite samples were built with a mix of CW samples: C1 with CW1, CW4 and CW6, C2 with CW2, CW5 and CW7, C3 with CW3 and CW8. No duds or leaching broken casings were present on the site, but sampling was done carefully with the presence of a CF ammunition specialist for security purposes.

3.3 14 Wing Greenwood

The strategy of sampling for CFB Greenwood was the same as for CFB Gagetown ranges. Only surface soil samples were authorized because of the level of clearance. Because the range was covered with small trees, bushes, and plants and the soil was sandy covered with grass, we were limited in location of sampling. But some spots of sand and topsoil could be seen and samples were taken (location of the samples is shown in Fig. 8). A total of seven soil samples, labeled GW1 to GW7, were taken all around the site in such a way to cover the area. Each soil samples consisted of circular composite built out of approximately 10 sub-samples taken randomly in a circular way around a fixed point, at an average distance of 0.5 m around the point. In addition, 4 wells built by 14 Wing Greenwood for groundwater monitoring were sampled. The locations of wells GWP1 to GWP4 are indicated in Fig. 8. Also, all water samples were collected as directed by Ref. 6.

3.4 CFAD Bedford

The objective of the sampling at CFAD Bedford was to assess the degree of contamination by energetic materials on the surface soil. We divided the site into two areas because of their differences. As suggested by the ammunition specialist, Area A was sampled at spots where OB/OD activities were taking place (see Fig. 9). A total of 5 soil samples, named B1 to B5, were taken in Area A. Sampling was made easy because limited

vegetation and sandy soil was present. Each soil sample consisted of circular composite built out of approximately 10 sub-samples taken randomly in a circular way around a fixed point, at an average distance of 0.5 m around the point. Three soil samples (B6 to B8) were taken beside the concrete pad shown in Area B. (Fig. 9) where, as suggested by CFAD personnel, some OB/OD activities had been taking place. Because heavy grass was present around the concrete pad, with the approval of the ammunition specialist, we scratched the grass using a shovel in order to sample soil.

4.0 EXPERIMENTAL

DREV's team collected samples at CFB Gagetown, 14 Wing Greenwood and CFAD Bedford. The Environmental Group in the Energetic Materials section analyzed all the samples collected during this sampling campaign at DREV. Prior to the analysis, commercially available field screening methods were used during all the sampling campaign. The colorimetric method (CM) was used at CFB Gagetown and the enzyme immunoassay (EIA) test kits were used at 14 Wing Greenwood and CFAD Bedford.

4.1 Chemicals and Equipment

All standards for explosive analysis were obtained from Accustandard, standards for EPA 8330 method (Ref. 13). All acetone used for soil extraction, homogenization of soil samples and glassware cleaning was reagent grade and was obtained from Fisher Scientific. The methanol used in laboratory for the HPLC eluent was Fisher Scientific HPLC grade. Deionized water was used in the field for cleaning and for addition in acetone extracts. Laboratory grade water was used for preparation of the HPLC eluent and the Sep-Pak extraction was obtained from a Millipore Milli-Q Type 1-reagent grade water system at DREV. HPLC grade acetonitrile from Fisher Scientific was used to perform the cartridge solid-phase extraction using prepacked cartridges of Porapak RDX Sep-Pak (6 cc, 500 mg) obtained from Waters Corporation. HPLC laboratory analyses performed at DREV were done with a Hewlett-Packard Model 1100 equipped with a diode array UV detector HP Model G1315A. HPLC laboratory analysis were performed using a LC-C18 column (Supelco) eluted with 1:1 methanol-water at 1.2 ml/min for 10 minutes. Absorbance was recorded at 254 nm in the peak height mode. Finally, both field screening methods were obtained from Strategic Diagnostics Incorporated (SDI).

4.2 Sample Treatment and Laboratory Analysis

For all sampling campaigns conducted at CFB Gagetown, 14 Wing Greenwood and CFAD Bedford, the soil samples were kept cold, in the dark and frozen from Day 1 until processed. Samples were brought with us to DREV at the end of the sampling campaign. Individual soil samples in Ziploc plastic bags were shaken and kneaded and then emptied in glass pans. The soils were further homogenized by breaking up clumps with gloved hands and stirring in acetone. When dry, the soils were extracted with acetonitrile by sonication, as described in the EPA method 8330 (Ref. 13).

4.3 Field Screening Methods

Field screening methods were used to rapidly detect TNT, RDX and HMX in the field. Field screening methods promote safe sampling procedures and significantly reduce analytical costs. Field screening methods were used on all sites during the sampling campaign. The colorimetric field screening methods were used on both sites at CFB Gagetown, while the enzyme immunoassay field screening method was used at 14 Wing Greenwood and CFAD Bedford. More details about the field screening methods can be found in (Refs. 6 and 8) thus, they will not be discussed in this report. The colorimetric field screening method has always been found to be the best to use, with excellent correlation with the laboratory methods. The least detectable concentration for the colorimetric field screening method is 0.7 mg/kg for TNT and 0.8 mg/kg for RDX and HMX.

The enzyme immunoassay (EIA) field screening method was used at 14 Wing Greenwood and CFAD Bedford. It is a semi-quantitative method giving a percentage rate of explosive contamination. This percentage can be later converted to mg/kg concentration. The detection limit of the EIA method for TNT is 0.5 mg/kg to 5 mg/kg in soil and 5 μg/L to 45 μg/L in water, while the detection limit for RDX is 0.5 mg/kg to 6 mg/kg in soil and 5 μg/L to 45 μg/L in water. It is important to mention that false positive results have been observed in the past in soil and water samples with the EIA method. Equipment supplier studies show that DTECH EIA field screening method has a false positive rate of 4% (Ref. 14).

5.0 RESULTS

The results are reported for each site separately; only cyclo-1,3,5-trimethylene-2,4,6-trinitramine (RDX), TNT and HMX were quantified in order to detect the presence of one of these three explosive residues.

5.1 Wellington Antitank Firing Range, CFB Gagetown

The laboratory results obtained during the sampling of the Wellington Antitank Firing Range are reported in Table I. The eleven samples collected show high levels of HMX, except for WX, a sample taken between Targets 1 and 2 near a stump shown in Figs. 2 and 6. The concentrations are ranging from 66 to 1315 mg/kg. One sample (W1D) was co-contaminated by RDX, which is present as a production impurity in HMX, but to a much smaller extent. The concentration detected for the W1D sample was 0.94 mg/kg of RDX. TNT contamination was detected in most samples, except for the samples W1A, W1C, WX, W3B and W3C. The TNT concentrations did not show a correlation with the HMX concentration found in the ratio that we could have expected (30:70, TNT:HMX), based on the melt-cast octol formulation (Ref. 15). The ratio observed between the HMX and TNT concentrations were much lower than expected, probably due to a rapid leaching of more soluble TNT in the soils. This sampling demonstrate that the Wellington Antitank Firing Range is contaminated mainly by HMX at high levels.

The colorimetric field screening method was used to detect rapidly TNT and HMX in the field and the results are reported in Table I. The results obtained in the field screening method were inconsistent with those obtained in laboratory for HMX. This was caused by a lack of resources on the site; samples were not diluted and reanalyzed after reaching near 200 mg/kg, the upper detection limit for HMX of the colorimetric field screening method. So even if the results were inconsistent, the methods gave good indication that the samples were contaminated at a concentration level higher than their upper detection limit (200 mg/kg).

5.2 Castle Grenade Range, CFB Gagetown

The Castle Grenade Range shows a presence of RDX at low concentration, with the highest result at 47 mg/kg as reported in Table II. As for the Wellington Antitank Firing Range, the colorimetric field screening method was used. Only the samples C1, C2, and

C3 were done due to a lack of on site resources. The results obtained by the field screening method are inconsistent with those obtained in the laboratory for RDX and TNT. Since our past studied show that the colorimetric field screening method give excellent results (Ref. 10), errors from the laboratory analysis are to be evaluated. The Castle Grenade Range samples were not analyzed before the maximum holding time of 8 weeks, as suggested in (Ref. 6). Thus, the samples might have degraded during that time. Since non-correlated results were obtained, we cannot tell if the laboratory results are sustainable, however, with the field screening method results we can evoke that there is a low concentration in RDX and TNT on site.

5.3 14 Wing Greenwood

The site sampled at 14 Wing Greenwood did not show any concentrations of RDX, HMX or TNT in the soil, as reported in the laboratory results of Table III. However, the field screening method shows a potential contamination with RDX and TNT in some samples, as reported in Tables III and IV. The enzyme immunoassay (EIA) gave results ranging from 0.5 to 0.6 mg/kg in soil and from 5 to 8.5 μg/L in water where the laboratory method gave non-detected explosive contamination for all samples. Possible natural decontamination might be the cause; soil samples were analyzed later than the maximum holding time of 8 weeks at 4°C. However, water samples were analyzed before the recommended 50 days, but still inconsistent results were obtained by the field screening method compared to the laboratory analysis. Identifying exactly why inconsistent results were obtained will need further research but three possible errors can be pointed out. First, the EIA field screening method used rigorous procedures that might easily lead to erroneous reading. Moreover, the enzyme immunoassay field screening method has a false positive rate of 4% (Ref. 14). One other major source of error can be attributed to the fact that even if the samples were analyzed before the recommended 50 days, they were still analyzed 30 days after sampling. At such a low concentration, natural attenuation can take place and lead to the decontamination of the sample. Unfortunately, no definitive conclusion can be drawn from those results. However, due to many positive results, a possible low contamination of RDX and TNT can be suspected with a concentration ranging from 0.5 to 0.6 mg/kg in soil and from 5 to 8.5 μg/L in water, but further analysis will have to be done.

5.4 CFAD Bedford

The site sampled at CFAD Bedford showed a non-presence of RDX, TNT and HMX. The laboratory results showed non-contamination of explosive in our samples, as reported in Table V. As for the 14 Wing Greenwood site, enzyme immunoassay field screening method was used on site. The results obtained are reported in Table V. The field screening method indicated a potentially RDX contamination of 0.8 mg/kg at B5, which does not correlate with the results found by the laboratory method. A possible error at the Greenwood site can be pointed out, the false positive rate of the EIA field screening method being 4%, as suggested by the supplier (Ref. 14), the B5 result can be attributed to a false positive result. Therefore, we can conclude that there was no detectable RDX, TNT or HMX contamination in samples from CFAD Bedford.

5.5 Identification of the Contamination Source

According to our past studies (Ref. 10), for the source of contamination of the Wellington Antitank Firing Range the main contamination source suspected for antitank ranges is the M72 ammunition. By having talked to many CF military personnel and by having seen many antitank ranges, we noticed that the M72 antitank ammunition has a very high dud rate. It has been demonstrated at WATC Wainwright, Alberta, Canada that this ammunition can reach more than 50% "dud producing" rate when fired under the best conditions. So, many duds can break when hitting the target or rocks and the explosive melt-cast formulation might be exposed to the environment. A picture of a M72 at WATC Wainright broken on the ground leaching explosive is shown in Fig. 1. No HMX contamination was found in the sample WX located between Targets W1 and W2, proving that there is less contamination found away from targets.

For the source of contamination of the Castle Grenade Range, the low contamination of RDX is coming from the accumulation through the years of post-detonation residues of grenades and C-4. The M-67 grenade used on this site contains Compound B, made of 60% RDX and 40% TNT. C-4 is used also to detonate unexploded grenades on site; it contains RDX at 90%. At 14 Wing Greenwood, no information is available about the potential source of contamination. Finally, at CFAD Bedford there is no source of contamination since no significant contamination was found.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The explosive contamination found on the surface at those sites is low and negligible, except for the Wellington ATR where we found a high level of HMX contamination on the surface. Thus, we can confirm that the contamination on many ATRs in Canada is due to the M72 weapons system, which has a high dud rate and produces many broken casings that expose the Octol on the ranges, this leads soil and groundwater contamination by HMX and TNT. We would recommend that DND take action in order to minimize this unfortunate impact in the future by causing in the same no inconvenient on training or operations taking place on site. One possible solution that will need to be investigated is the correction of the high dud rate problem of the M72 munitions. On site, we have seen M72 ammunition hit the target directly without having detonated (as shown in Fig. 2).

For all other sites, except for the 14 Wing Greenwood site, low levels to a non-presence of contamination by explosives were found on the surface, demonstrating that the detonation of ammunition is a relatively clean process, which leads to a minimal impact on the environment. At 14 Wing Greenwood, further analysis and evaluation will have to be completed in order to correctly characterize the site, since no conclusive results were obtained.

With the field screening results from the Castle Grenade Range and the 14 Wing Greenwood site, we have demonstrated that samples not analyzed before the maximum holding time, as indicated in Ref. 6, might degrade and lead to erroneous results. We might have also demonstrated that samples from those sites were containing active microbial strains that led to their own decontamination. Past studies have demonstrated that samples with large microbial activity might lead to a biotransformation of the explosive contaminants (Refs. 6 and 16).

For all sites characterized, since we have assessed surface soil only, we would suggest that further analysis be done for sub-surface soil and groundwater. Because TNT is more mobile and more rapidly dissolved than HMX and RDX in the infiltrated water and is suspected to leach and bind to organic matter in sub-surface soil strata. Moreover, TNT degrades into metabolites that are even more soluble than TNT.

In general, for all sites that might be in contact with explosives, care should be taken in collecting duds or post-combustion residues after each exercise or operation, thus

minimizing the spread of energetic materials in the environment and contamination. If these solutions are not feasible, then a level one clearance should be conducted more frequently on each site. Since the toxicity associated with explosives have been demonstrated in the past (Ref. 6), contaminated soil should be remediated where there is a possible exposure with personnel. Now, new remediation technology is available and has been demonstrated at our research facilities at CFB Valcartier (Ref. 17). At the present time, research is dedicated to developing a way to decontaminate in-situ, which would be the most appropriate way of decontamination for DND.

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TABLE I

Analytical results: Sampling of Wellington ATR, August 1998

SAMPLES	HMX mg/kg	RDX mg/kg	TNT mg/kg
W1D	681,6 (160)	0,9	8,1 (no result)
W1B	253,8 (no result)	nd	11,3 (no result)
W1C	153,3 (159)	nd	nd (nd)
W1A	66,1 (49)	nd	nd (<0.7)
WX	nd (<0.8)	nd	nd (nd)
WY	1160,0 (159)	nd	9,9 (<0.7)
W3D	141,6 (164)	nd	1,4 (nd)
W3B	1137,6 (174)	nd	nd (nd)
W3C	678,6 (>200)	nd	nd (nd)
W3A	1207,7 (158)	nd	2,9 (1.0)
W3 COMPOSITE	1315,8 (>200)	nd	2,0 (nd)

() : field screening method results
nd : not detected

TABLE II

Analytical results: Sampling of Castle Grenade Range, August 1998

SAMPLES	HMX mg/kg	RDX mg/kg	TNT mg/kg
C1	nd	nd (<0.8)	nd (<0.7)
C2	nd	nd (47)	nd (4)
C3	nd	0.5 (15)	nd (nd)
CW 1	nd	2,6	nd
CW 2	nd	3,9	nd
CW 3	nd	nd	nd
CW 4	nd	nd	nd
CW 5	nd	1,1	nd
CW 6	nd	nd	nd
CW 7	nd	<0.8	nd
CW 8	nd	nd	nd

() : field screening method results
nd : not detected

TABLE III

Analytical results: Soil sampling of the 14 Wing Greenwood site, August 1998

SAMPLES	HMX mg/kg	RDX mg/kg	TNT mg/kg
GW 1	nd	nd (0.6)	nd (nd)
GW 2	nd	nd (0.5)	nd (nd)
GW 3	nd	nd (nd)	nd (nd)
GW 4	nd	nd (0.6)	nd (nd)
GW 5	nd	nd (nd)	nd (nd)
GW 6	nd	nd (nd)	nd (nd)
GW 7	nd	nd (0,6)	nd (nd)

() : field screening method results
nd : not detected

TABLE IV

Analytical results: Water sampling of the 14 Wing Greenwood site, August 1998

SAMPLES	HMX ug/L	RDX ug/L	TNT ug/L
GWP 1	nd	nd (5)	nd (5)
GWP 2	nd	nd (8,5)	nd (8)
GWP 3	nd	nd (5)	nd (nd)
GWP 4	nd	nd (nd)	nd (5)

() : field screening method results
nd : not detected

TABLE V

Analytical results: Sampling of the CFAD Bedford site, August 1998

SAMPLES	HMX mg/kg	RDX mg/kg	TNT mg/kg
B 1	nd	nd (nd)	nd (nd)
B 2	nd	nd (nd)	nd (nd)
B 3	nd	nd (nd)	nd (nd)
B 4	nd	nd (nd)	nd (nd)
B 5	nd	nd (0.8)	nd (nd)
B 6	nd	nd (nd)	nd (nd)
B 7	nd	nd (nd)	nd (nd)
B 8	nd	nd (nd)	nd (nd)

() : field screening method results
nd: not detected

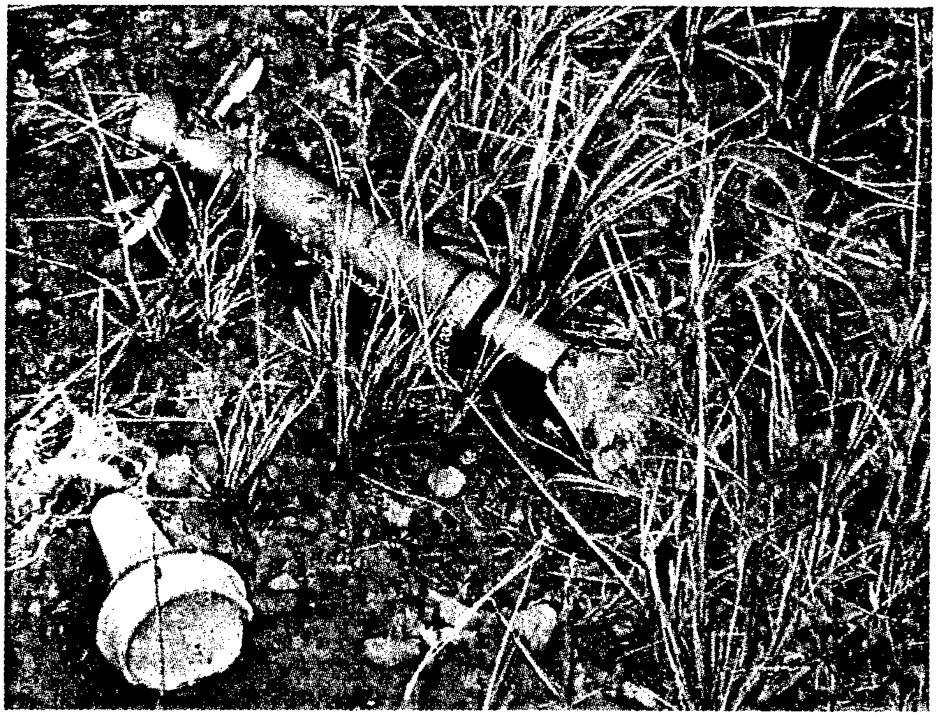


FIGURE 1 – Duds of M72 leaching octol in the environment

FIGURE 2 – Unexploded M72 in a stump

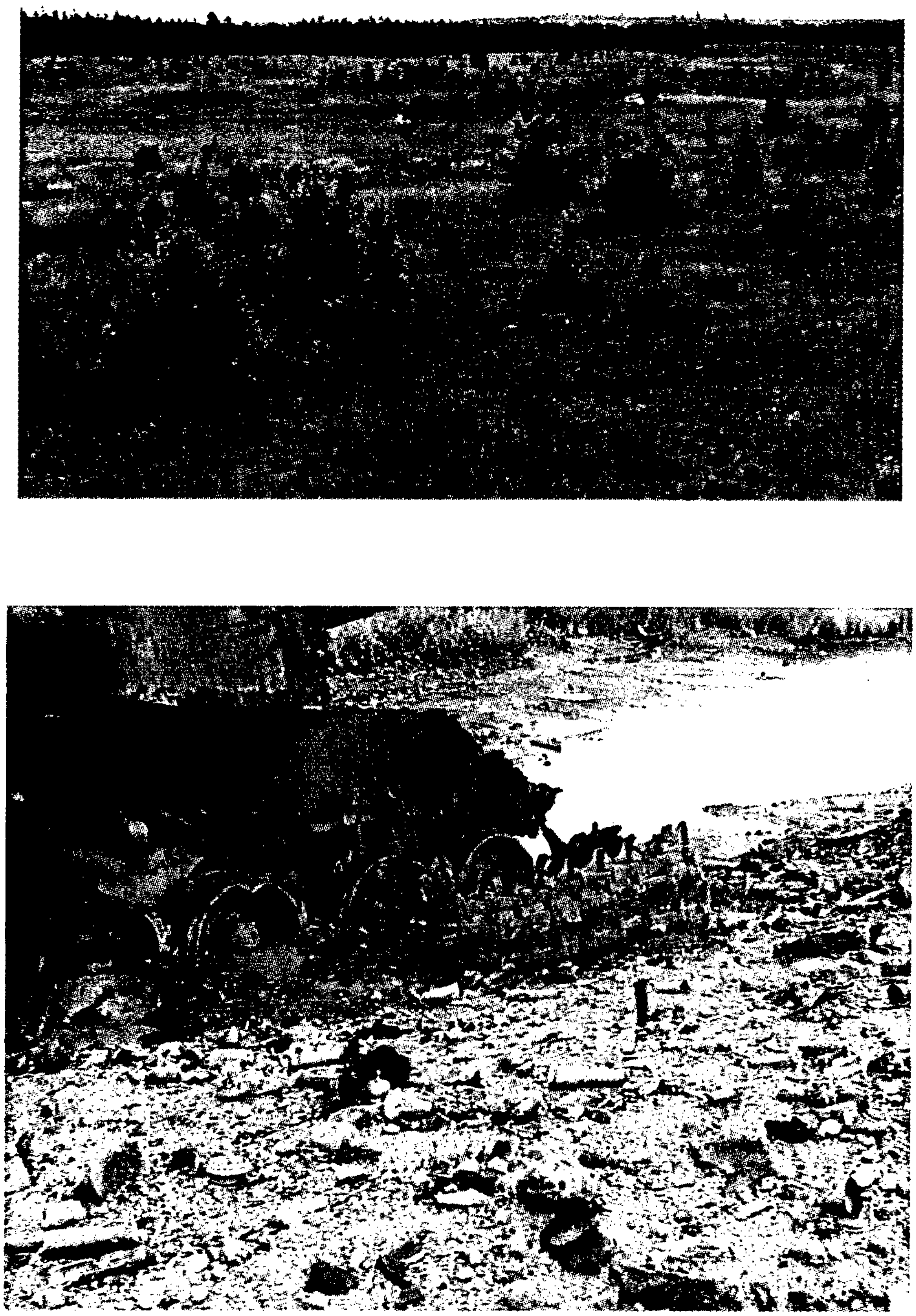
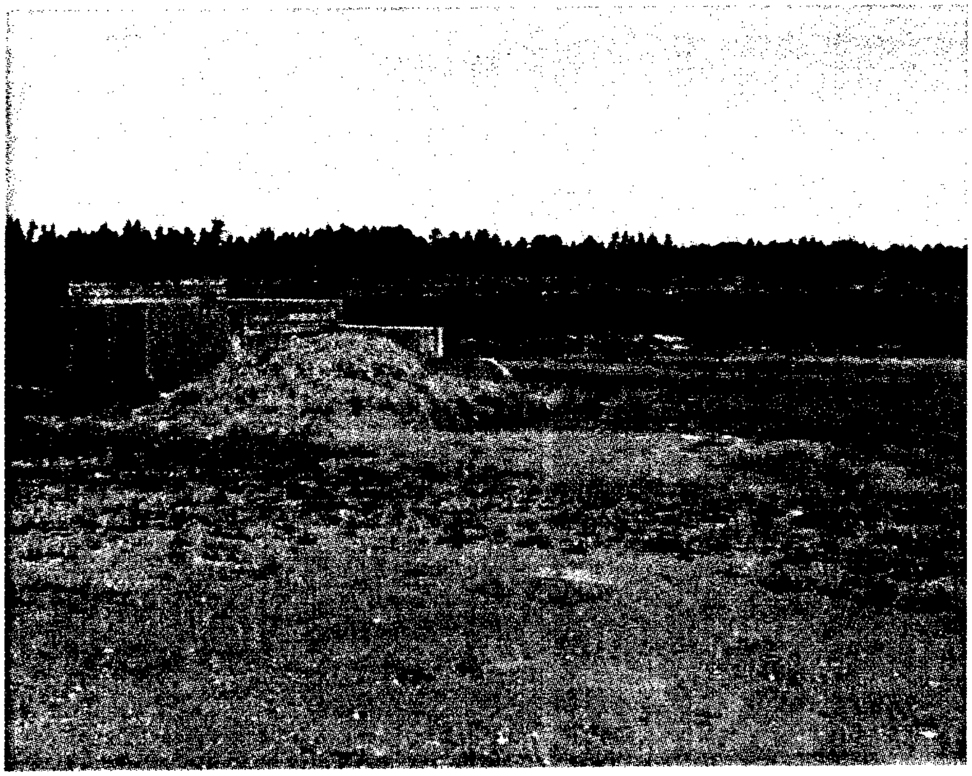


FIGURE 3- Pictures of the Wellington Antitank Range



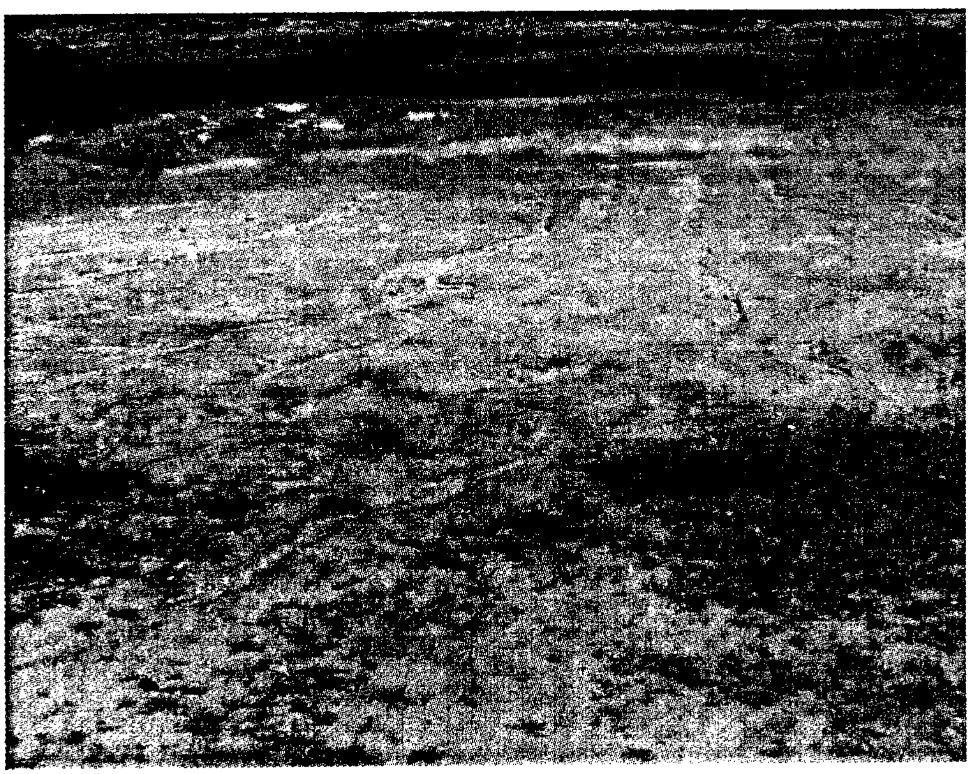


FIGURE 4 – Pictures of Castle Grenade Range, CFB Gagetown

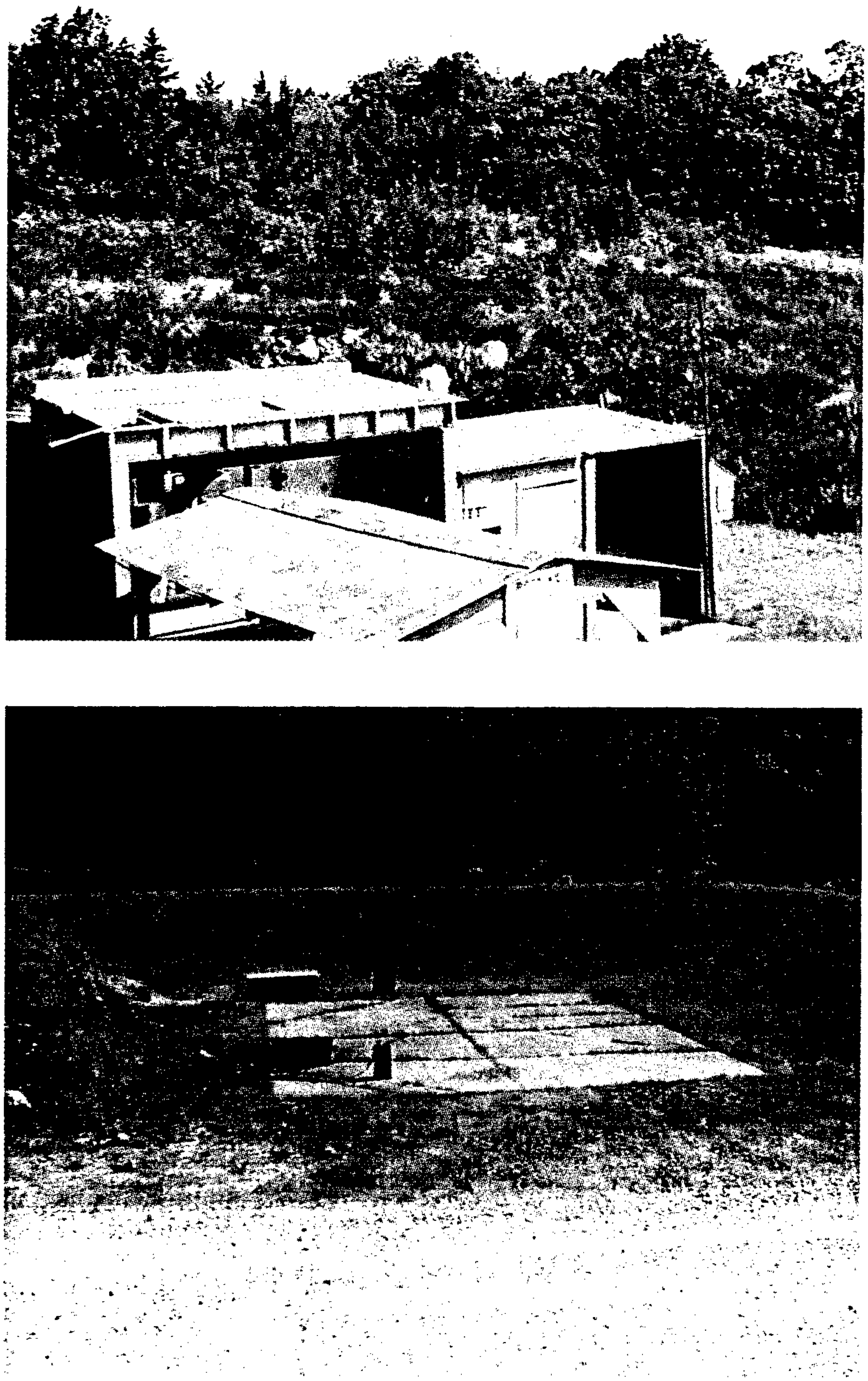


FIGURE 5 – Pictures of the CFAD Bedford site

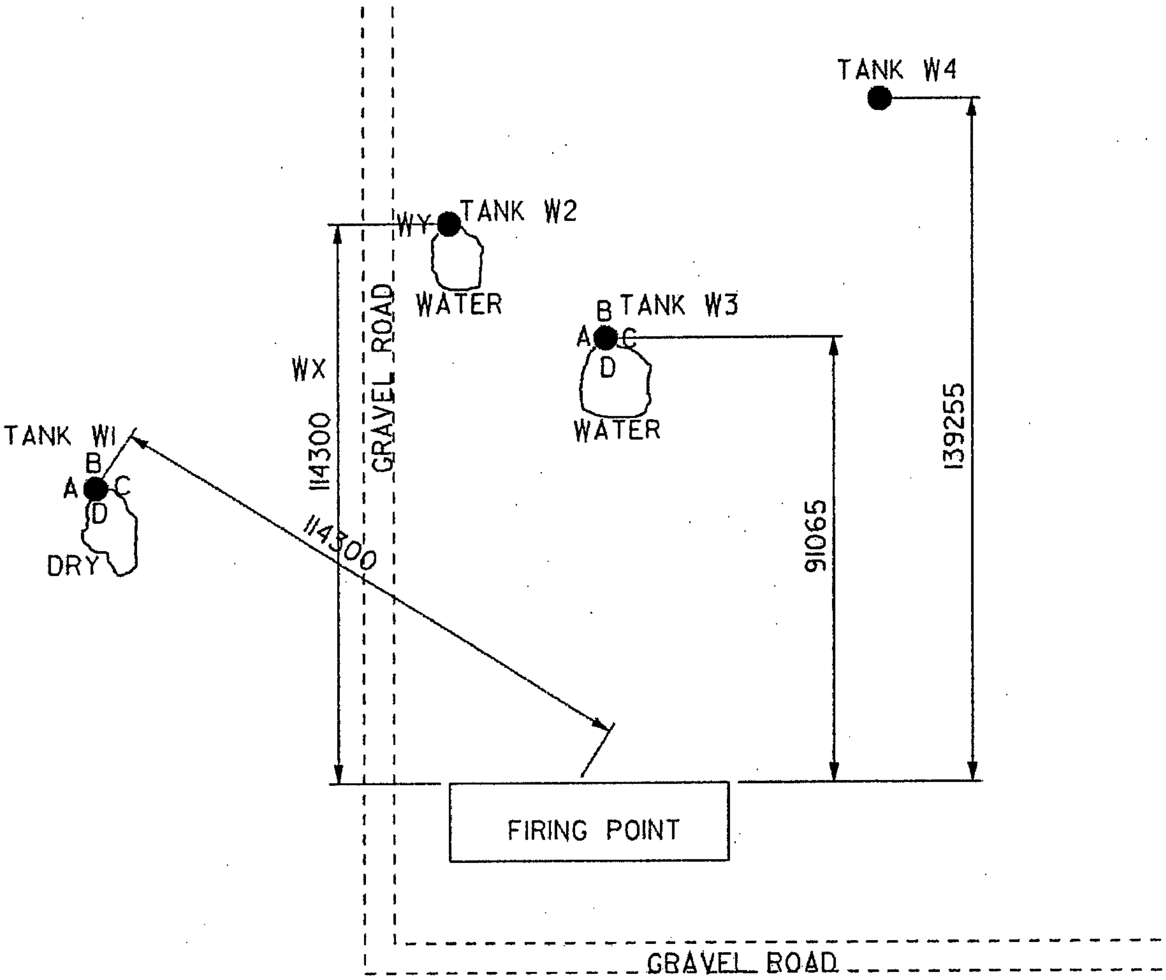


FIGURE 6 – Sampling plan, Wellington ATR, CFB Gagetown

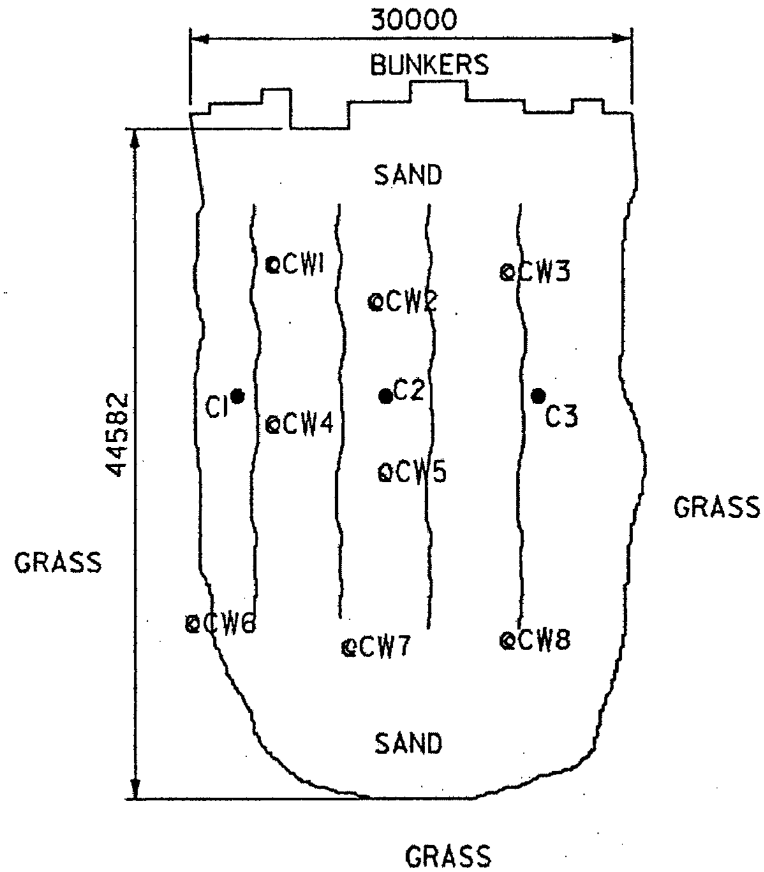


FIGURE 7 – Sampling plan, Castle Grenade Range, CFB Gagetown

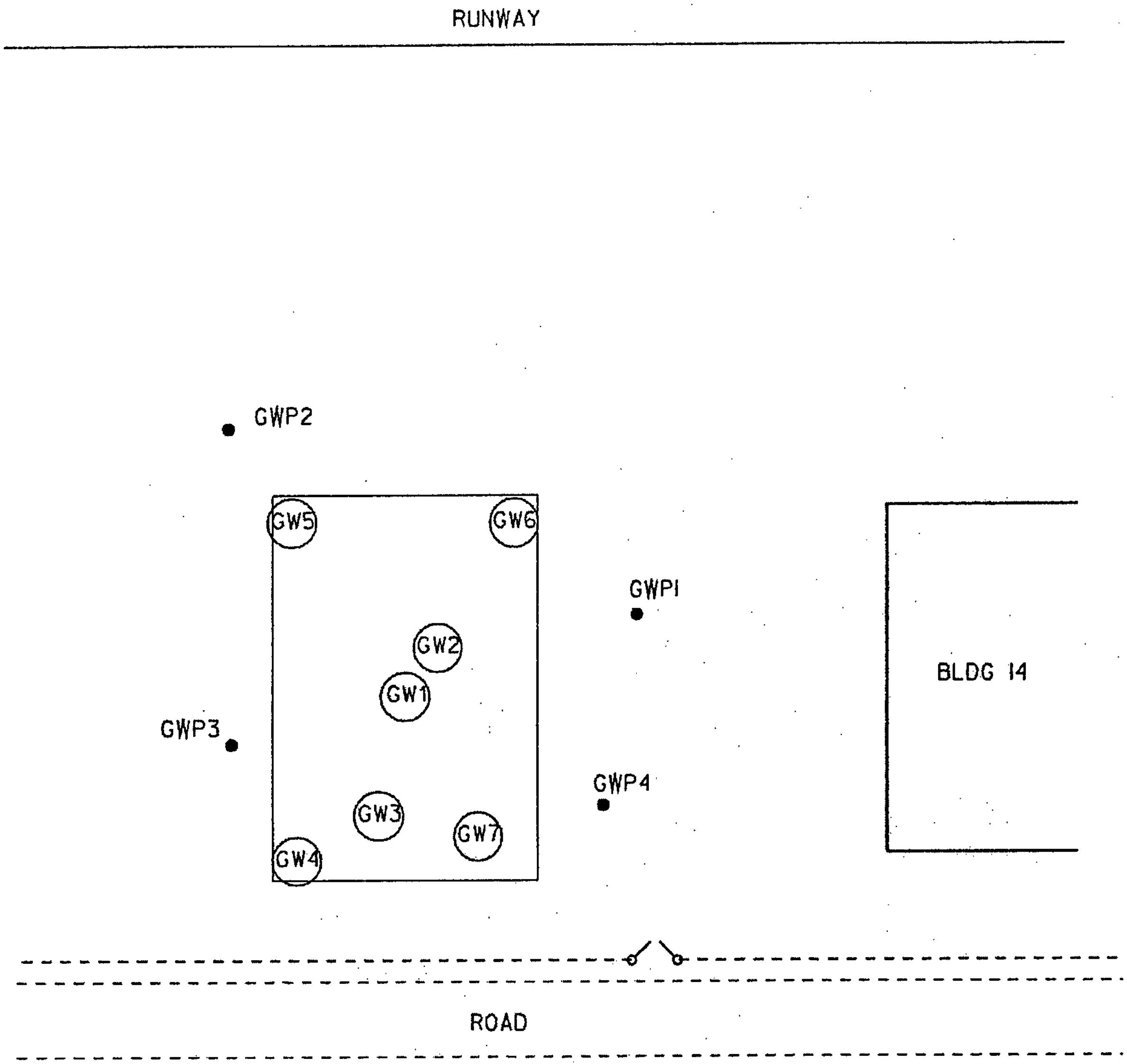


FIGURE 8 – Sampling plan at the 14 Wing Greenwood site

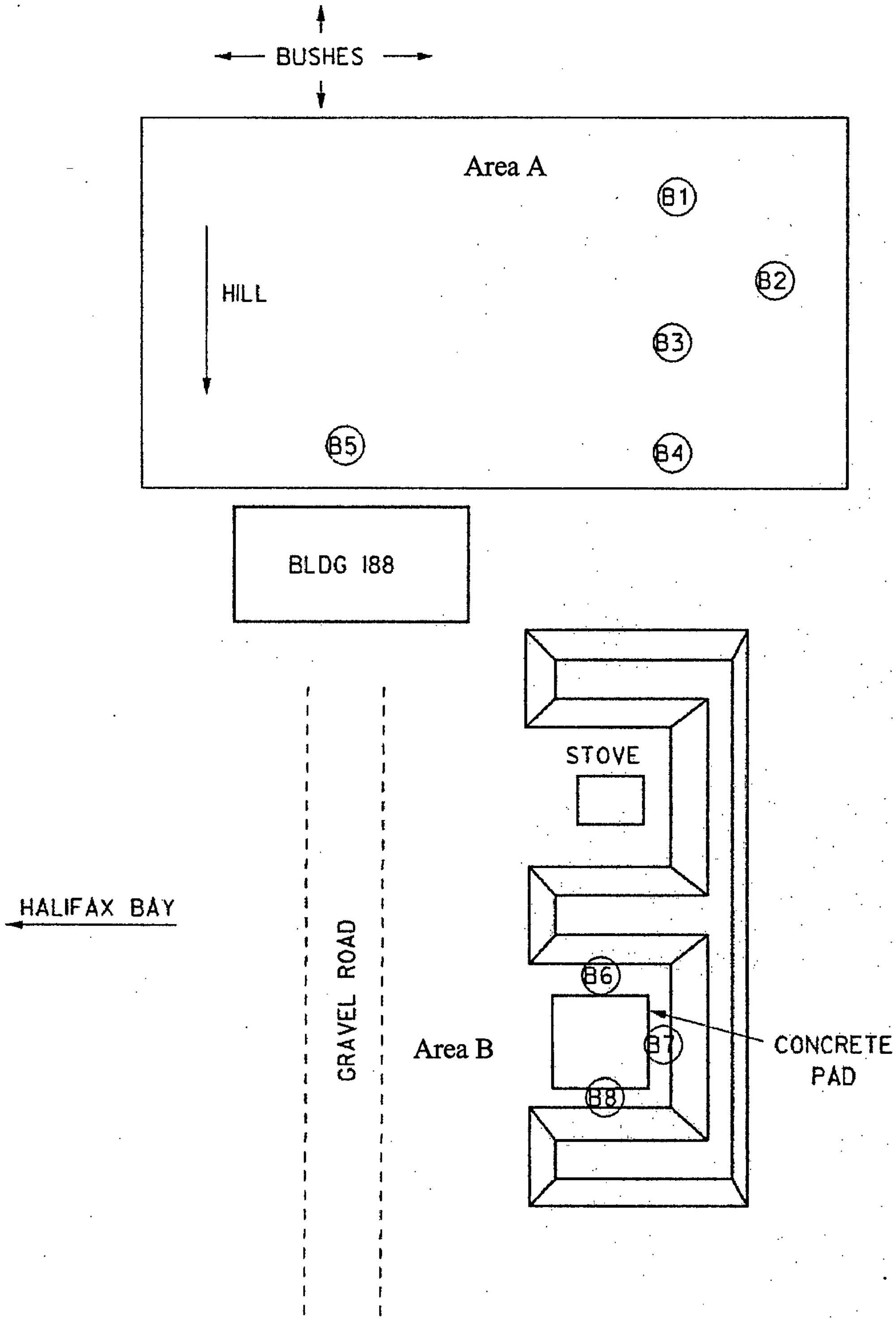


FIGURE 9 – Sampling plan at the CFAD Bedford site

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Some activities of the Canadian Forces such as firing practice, storage and demolition procedures may cause the dispersion of energetic compounds in the environment. These compounds should be closely monitored due to their highly specific physical, chemical and toxicological properties. In Canada, limited efforts have been spent in the past to examine this particular environmental threat. This report details the characterization of four potentially explosives-contaminated sites located at Canadian Forces Base (CFB) Gagetown, 14 Wing Greenwood and at Canadian Forces Ammunition Depot Bedford. The sampling and analytical methods are described and the results are presented. In general, our results show a non-presence to a low contamination level (<15 mg/kg). However, the Wellington Antitank Firing Range at CFB Gagetown showed relative high levels of contamination by HMX, a high explosive compound used in many antitank rockets. This work should help the Canadian Forces to pursue their operational activities, while minimizing the impacts on the environment by providing a better comprehension of the source of contamination and helping to minimize the environment impacts in the future.

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